S-5/PHSH/CC-11/19

TDP (Honours) 5th Semester Exam., 2019

PHYSICS

(Honours)

ELEVENTH PAPER (CC-11)

Time : 3 Hours

Full Marks : 60

The figures in the margin indicate full marks.
Candidates are required to give their answers in their own words as far as practicable.

Section - A

1. Answer any *six* of the following questions : 2×6=12

   (a) Explain the meaning of stationary states in quantum mechanics.

   (b) What do you mean by a free particle?

   (c) What is the significance of zero point energy?

   (d) Plot the ground state eigenfunction of the hydrogen atom as a function of the distance *r*.

   (e) State Larmor's theorem.

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(f) What is Stark effect?

(g) The magnesium atom has two 3s electrons outside filled inner shells. Find the term symbol of its ground state.

(h) Calculate Lande g factor for the terms $3^2S_{1/2}$ and $3^2P_{1/2}$.

Section - B

Answer the following questions : $12\times4=48$

2. (a) (i) State and prove Ehrenfest's theorem in quantum mechanics.

(ii) What is Hermitian operator?

Show that two eigenfunctions of Hermitian operator, belonging to different eigen values are orthogonal to each other.

(iii) Write an expression for the probability current density and calculate the same for the wave function $\psi=e^{ikr}/r$, where $r^2=x^2+y^2+z^2$, and interpret the result.

$(1+3)+(1+3)+(1+2+1)$

Or,

(b) (i) Derive Heisenberg's uncertainty relation for the position and momentum variables.

(ii) Show that an electron can not exist inside the nucleus.

(iii) According to classical description, an electron moves with kinetic energy 1 keV. It corresponds to a Gaussian wave packet of width 10 nm. Find the time in which the width increases to 20 nm.

(iv) Show that $\left[\hat{x},\hat{p}_x^n\right]=i\hbar n\hat{p}x^{n-1}$ and $\left[\hat{p}_x,x^n\right]=-i\hbar nx^{n-1}$. $3+2+3+(2+2)$

3. (a) (i) What is harmonic oscillator? Establish Schrödinger's equation of a linear harmonic oscillator. Draw the wave function of ground state and first excited state it.

(ii) Explain whether the ground state wave function of a one-dimensional harmonic oscillator is an eigenfunction of the momentum operator.

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(iii) Obtain an approximate analytic expression for the energy level in a square well potential $(b = 0)$ when $v_0 a^2$ is slightly greater than $\pi^2\hbar^2/8m$.

(iv) Explain the significance of the various energy levels of the hydrogen atom which has only one orbital electron. 5+2+3+2

Or,

(b) (i) Write down the radial part of the time-independent Schrödinger equation for the hydrogen atom and hence find the relation between the eigen energies (E_n) and the principal quantum number (n).

(ii) Unnormalized hydrogenic 2P-state wave function for $m = 0$ is $\left(\frac{r}{a_0}\right) \exp\left(\frac{-r}{2a_0}\right) \cos\theta$.

Determine the normalization constant.

(iii) Show that the most probable position of the electron of the hydrogen atom in the ground state is given by the first Bohr radius (a_0). Also calculate the probability that the electron lies in a sphere of radius R.

5+2+(3+2)

4. (a) (i) State and explain Moseley's law. Show that this law can be deduced from the modified Bohr's theory of hydrogen spectra.

(ii) How does the continuous x-ray spectrum arise? Why does it have a short wavelength limit?

(iii) Give a detailed account of the vector atom model. (3+3)+(2+2)+2

Or,

(b) (i) Describe Stern and Gerlach's experiment of studying the atomic rays in a non-homogeneous magnetic field. Discuss what the experimental results establish.

(ii) Illustrate with diagrams the zeeman splitting of sodium D_1 and D_2 lines.

(iii) What is Bohr magneton? What is it's physical significance? Calculate its value.

(iv) Find the minimum magnetic field needed for the Zeeman effect to be observed in a spectral line of 400 nm wave length when a

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spectrometer whose resolution is 0.010 nm is used. (3+1)+2+3+3

5. (a) (i) State Pauli's exclusion principle and use it to find the electronic configuration of the sodium atom whose atomic number is 11.

(ii) Why is the ground state of the hydrogen atom not split into two sublevels by spin-orbit coupling?

(iii) What are the possible values of L for a system of two electrons whose orbital quantum numbers $l_1 = 1$ and $l_2 = 3$?

(iv) Find the S, L and J values that correspond to each of the following states :

$^1S_0$, $^3P_2$, $^2D_{3/2}$. (1+2)+2+1+(2+2+2)

Or,

(b) (i) Distinguish between singlet and triplet states in atoms with two outer electrons.

(ii) The lowest vibrational states of the $^{23}Na\,^{35}Cl$ molecule are 0.063 eV apart. Find the approximate force constant of this molecule.

(iii) What is Raman effect? Discuss the characteristics of Raman lines. Explain why Stokes lines are more intense than anti-Stokes lines. Indicate the importance of Raman effect. Give one practical use of Raman spectra. 2+2+(1+2+2+2+1)